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GUIDELINES FOR DESIGN, INSTALLATION AND TESTING OF TIMBER SEASONING KILNS (COMPARTMENT TYPE WITH CROSS-FORCED AIR CIRCULATION)

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GUIDELINES FOR DESIGN, INSTALLATION AND TESTING OF TIMBER SEASONING KILNS (COMPARTMENT TYPE WITH CROSS-FORCED AIR CIRCULATION)

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GUIDELINES FOR DESIGN, INSTALLATION AND TESTING OF TIMBER SEASONING KILNS (COMPARTMENT TYPE WITH CROSS-FORCED AIR CIRCULATION)

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 15 March 1974, after the draft finalized by the Timber Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A large number of timber seasoning kilns have been installed in the country during the last four decades or so and many more are expected to be installed in the coming years with the rapidly increasing place of industrialization and the growing awareness of quality control in seasoned timber for various jobs. In the early years, kilns equipment used to be imported into the country, but now a purely indigenous kiln equipment manufacturing industry has got established on the basis of research work carried out at the Forest Research Institute & Colleges, Dehra Dun.

0.3 The design of a timber seasoning kiln has a direct bearing on the quality of seasoned timber produced with regard to seasoning degrade, moisture content uniformity and freedom from stresses after drying. It also directly affects the efficiency of the seasoning operation by way of minimizing heat losses, ensuring uniformity of drying rate between different portions of the stack and thereby avoiding long periods of treatment that become otherwise essential to equalize moisture content towards the end of drying.

0.4 The kilns that have been installed have varied widely in design features, such as constructional materials for the chamber, nature of air circulation (forced or thermal), mode of heating and humidification, venting system, baffling and several other minor but important details of equipment that affect performance. The need has been felt to specify essential design features and minimum performance requirements of timber seasoning kilns that would be helpful to kiln manufacturers and users in production or selection of efficient kilns conforming to the requirements of quality control in seasoning.

0.5 Timber seasoning kilns may be classified as follows:

a) In respect of mode of working:
   1) compartment type, and
   2) progressive kilns or tunnel driers.

b) In respect of mode of heating:
   1) steam-heated (for extra humidification),
   2) furnace-heated, and
   3) indirect-heated.

c) In respect of means used to obtain air circulation:
   1) internal fan,
   2) external blower, and
   3) natural draught or thermal circulation.

0.5.1 Progressive kilns or tunnel driers have been found suitable only for stock of uniform species, thickness, quality and moisture content. These have been used to a limited extent only for veneers and packing case timbers.

0.5.2 Compartment type of kilns are in common use in India. Their mode of heating and air circulation may be different as stated under **0.5** (b) and (c) and as mentioned below:

a) *Steam-heated, internal fan or external blower or natural draught kiln* — Use of boiler steam for extra humidification in these kilns makes them suitable for seasoning almost any kind of timber. They need a boiler and motive power for driving the fans, except in the natural draught kiln in which circulation is thermal. These kilns would be economical for sections up to 5 cm thickness of most of the timber (except the very refractory ones like sal), for seasoning from green condition. Thicker sections will have to be air seasoned from green condition to about 30 percent moisture content, and thereafter further seasoning can be completed in the kiln.

b) *Furnace-heated, internal fan kiln (wood-waste fired)* — This kiln is particularly designed to substitute cheap sawmill waste for supplying furnace gases for heating purpose in place of steam from a boiler. Where no arrangement for extra humidification of the kiln air is provided for, this kiln can be used onlyfor the rapid seasoning of packing case timber. It would not be suitable as such for seasoning thicker planks or scantlings or non-coniferous as there is appreciable fluctuation in temperatures, and the humidity of the air cannot be controlled at high levels to prevent cracking or relieve case hardening stresses as in steam-heated kilns. But if arrangement for extra humidification by water sprays or other means is provided, it may be used also for the latter class of timbers provided humidity of the kiln air as high as 90 percent can be attained quickly at the operating temperatures.

c) *Indirect heating thermal circulation furnace kiln (wood-waste fired)* — This is a cheap type of kiln which is primarily suitable for slow seasoning of timbers in thin sections, such as furniture class of timbers in planks up to 40 mm in thickness or bobbin blocks. Because of the sluggish air circulation drying tends to be non-uniform. Case hardening stresses in the dried timber cannot be relieved because of the absence of any arrangement for extra humidification.

0.5.3 *Air Circulation* — Air circulation may be either forced by means of an internal fan or external blower or may be natural by thermal circulation. Forced air circulation in a kiln with an external blower is more elaborate in design and generally costlier than the internal fan kiln. Uniform air circulation conducive to even drying in the timber stack is ordinarily more difficult to achieve in this type of kiln than in the internal fan type. Very few kilns of this type are presently in use for seasoning of planks and scantlings. The internal fan kiln is the most efficient for its cost and the most widely used kiln for all seasoning purposes.

Drying in a natural draught or thermal circulation kiln is generally slower than in the forced air circulation, internal fan or external blower kiln, because of the relatively sluggish air circulation. This kiln is not suitable for efficient seasoning of timber to uniform moisture contents for precision jobs, though the uniformity of moisture content in the dried material can be improved by partial pre-air seasoning before charging into the kiln and by prolonged drying in the kiln. It finds only limited use, such as for slow drying of bobbin and shuttle blocks.

0.5.4 No oil-fired furnace kilns have been used in India. Such kilns with efficient humidifying arrangement using auxiliary steam generation at atmospheric pressure by furnace heating are however in use in other countries. The use of electrically heated kilns with built-in arrangement for electrical generation of low-pressure saturated steam for extra humidification has also been limited on account of the higher costs of electrical energy.

0.6 In the formulation of the standard due weightage has been given to the international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard lays down the minimum performance requirements of compartment type, cross-forced air circulation timber seasoning kilns for efficient seasoning, and recommends essential features of equipment, design and installation to attain the desired performance. Progressive kilns or tunnel driers and natural draught or thermal circulation kilns are excluded from the scope of this standard because of their limited applicability and known drawbacks. Procedure for testing kiln performance has also been outlined.

2. MINIMUM PERFORMANCE REQUIREMENTS FOR COMPARTMENT TYPE CROSS-FORCED AIR CIRCULATION SEASONING KILNS

2.1 Efficient seasoning of timber within the minimum possible time consistent with a minimum of drying defects calls for certain minimum requirements with regard to air speeds past the timber surfaces in the stack, relative humidities that can be maintained and the uniformity of drying conditions within the kiln. Lack of an efficient humidifying arrangement exposes the timber to increased degrade through cracking and splitting as also makes case hardening relief impossible, particularly in thick and refractory timbers. Favourable air circulation speed and distribution are essential for efficient heat transfer from the heating system to the timber and to prevent the evaporated water vapour from stagnating at the timber surfaces in order to support rapid evaporation of moisture and maintain uniform drying conditions within the stack. Non-uniform drying conditions lead to huge moisture content differences in the stock towards the conclusion of the drying run, calling for time-consuming and uneconomical equalizing treatments and making uniform relief of case-hardening stresses extremely difficult, if not impossible.

2.2 The kiln shall be capable of attaining the operating temperatures from the ambient within reasonably short periods, say about 1½ hours, with a full load of green timber.

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*Rules for rounding off numerical values (*revised*).

2.3 The kiln shall be capable of attaining up to 90 percent relative humidity within a reasonably short period, say 15 min, with the timber charge near the desired final average moisture content and already heated up to the operating temperature.

2.4 The circulation of air shall be adequate and uniformly distributed, not less than 0·6 m/s in any layer of the timber stack. It should be reversible in direction through the stack. Air-speed measurements shall be done with the stacking space of the kiln fully stacked in length and height with 2·5 cm thick timber using 20 mm thick crossers.

2.5 The temperature indicators or recorders, both wet and dry, shall be accurate to within ±0·5°C over the range of temperatures likely to be used and shall be so installed that they register the condition of the heated air entering the timber stack in the hotest zone.

2.6 The maximum variation of dry bulb temperature from the indicator or recorder reading shall not be greater than ± 2·5°C at any position on the entering air side of the stack.

2.7 The maximum variation of wet bulb temperature from the indicator or recorder reading shall not be greater than ± 1°C at any position on the entering air side of the stack.

3. DESIGN, CONSTRUCTION AND EQUIPMENT

3.1 Kiln Chamber — A kiln chamber should be designed to reduce heat and vapour losses to the ambient, reduce vapour condensation on roof and walls, support the load of the equipment that is installed and give an extended life. Brick, concrete blocks, asbestos cement board, metal, and wood are materials that may be used to build the kiln chamber. Two types of chamber construction are adopted: (a) Masonry construction, and (b) Panel construction.

3.1.1 *Masonry Construction*

3.1.1.1 Walls shall be made of brick work. Concrete slabs are generally not preferred for wall construction because of their higher cost, larger heat and vapour transmission and tendency to large expansion cracks. However, when concrete is used, a cinder aggregate is to be preferred to gravel or crushed stone aggregate to reduce heat loss. The thickness of masonry walls shall not be less than 30 cm. The kiln roof shall be made of reinforced cement concrete slabs not less than 10 cm thick, with the underside nearly horizontal, but with sufficient pitch on the top to drain properly where a kiln is built-in an open location. The kiln shall be provided with a concrete floor at least 10 cm thick.

3.1.1.2 The walls and roof of a masonry kiln shall be coated on the inside with a good asphaltic or any other vapour-resistant paint that should be renewed periodically. The walls and roof, when built from hollow concrete slabs or tiles with air gap, shall also be provided with an effective membrane type of vapour barrier on the inside of the chamber like asphalt impregnated or coated felt, made with a high melting point asphalt to reduce heat and vapour loss and prevent condensation. Paints or coatings, if any, used on the exterior faces of the chamber shall be not of the vapour-resistant type.

3.1.1.3 The design calculation for the RCC roof, the construction of the chamber and its foundations shall follow standard civil engineering practices.

3.1.2 *Panel Construction* (*Including Prefabricated Construction*) — The kiln chamber may be built from steel and aluminium double panels, double panels of wood sheathing over a wooden frame, or wood or metal framing covered with double panels of asbestos-cement board. The panels may be prefabricated in standard modular units prefabricated kiln designs. Irrespective of the type of panel construction used, the following criteria shall apply:

a) The gap between double panels shall be filled with suitable insulating material. The thermal insulating value of the panel shall not be less than that of a 30 cm brick wall.

b) In metal panel construction, steel sheets shall not be used on the interior side of the chamber as they are liable to rapid corrosion under the humid and slightly acidic kiln atmosphere. The interior panels shall be made of aluminium sheets.

c) The construction should be such that the panels or prefabricated elements when joined together shall produce a vapour proof seal preventing ingress of moisture into the insulation. In case of wood or asbestos board double panel construction, an effective membrane type of vapour barrier (*see* **3.1.1.2**) shall be provided on the interior side of the chamber walls, preferably between the framing and the interior panel sheathing.

d) The roof in panel construction with wood shall incorporate an asphalted felt vapour barrier between two layers of wood sheathing on the underside, and the whole shall then be covered with a roofing of light-weight aggregate like cinder aggregate. With asbestos board roof, the asbestos board on the underside shall be covered with asphalted felt vapour barrier, and the whole shall then be coverd with a roofing of light-weight aggregate.

e) The roof in kilns of metal panel construction to be installed in the open (not under a shed) shall be covered with asphalted felt, made with high melting point asphalt.

3.2 KILN DOORS

3.2.1 Double panels of sheet metal, wood or asbestos boards on steel or wooden framing and filled inside with suitable insulating material may be adopted for kiln door construction. In sheet metal construction, steel sheet shall not be used on the interior side of the chamber, for which aluminium sheet shall be used. Doors made from wood or asbestos board shall be completely lined on the interior with aluminium sheet or shall incorporate an asphalted felt vapour barrier between the interior wood or asbestos sheathing and the insulation, to prevent ingress of moisture into the insulation. One-piece design is preferable to a double flap design for kiln doors. Kiln doors shall be provided with suitable heat-resistant gaskets and fastening arrangement to prevent vapour and heat losses.

3.2.2 Small inspection doors shall be provided in suitable locations in each kiln, in addition to the main kiln charging door, to allow the operator to inspect the kiln samples on either side of the timber stack during the drying operation. Suitable lighting arrangements may also be made. Latches provided in inspection doors shall be operable from the inside as well as the outside of the kiln.

3.3 Loading Arrangement — The type of kiln loading arrangement depends upon the user's requirement. Manual stacking inside the kiln is satisfactory only where the charge drying times of the timber being seasoned are excessive compared to stacking time or where there are frequent idle periods between charges. It is generally recommended that a kiln should be provided with kiln trucks or trolleys and tracks leading into the chamber so that timber stacking can be done outside the kiln to save time. A transverse track lay-out outside the kiln, with track changing equipment or a transfer truck and a spare set of trolleys, is essential to have a full set of loaded trolleys ready so that the kiln can be recharged without loss of time as soon as seasoned timber trolleys are taken out. Truck loading also enables the entire length and height of the kiln to be completely stacked with timber, which is difficult to do with manual loading.

3.4 Chamber Dimensions and Stacking Capacity — The chamber dimensions depend upon the quantity and maximum length of the timber to be seasoned, the location of the fans and upon whether the kiln is intended to accommodate a single or double row of stacks in the width.

3.4.1 Stacking capacity of a kiln shall be expressed in standard terms as the maximum volume of 2·5-cm thick timber that can be stacked using 20 mm thick crossers.

3.4.2 For the purpose of determining the dimensions of a kiln chamber to suit a specified stacking capacity, the maximum dimensions of the timber stack shall first be fixed after taking account of the provision under **3.4.1**, and the following requirements:

a) The length of the stack has to be reckoned as equal to the maximum length of timber that may be stacked.

b) The length of air transverse across the stack, and the width of the stack in a cross-forced air circulation kiln, should not exceed 2·1 m, to avoid large differences of drying conditions between the entering and leaving air sides.

c) The height of the stack should be limited to 3 m with manual stacking but may be increased if mechanical stacking devices are adopted.

3.4.3 The internal dimensions of the cross-forced air circulation kiln chamber, which are to be determined after fixing the maximum stack dimensions in accordance with clause **3.4.2** shall provide for the following essential requirements:

a) The internal length of the chamber shall be greater than the maximum length of timber that may be stacked, by a suitable amount, to provide for adequate clearance between the stack ends and the end walls. The difference, however, shall not exceed 30 cm, except in kilns in which stacking is done inside where it may be up to a maximum of 60 cm.

b) The internal width in case of a single-stack kiln chamber (internal fan or external blower type) shall provide for a minimum of 60-cm wide vertical plenum space on either side of the stack between the stack and the side walls, extending along the entire length of the kiln. In a double stack kiln, an additional vertical plenum space, at least 1 m wide and running along the entire length of the kiln between the double rows of stacks, shall also be provided. In internal fan kilns with side-mounted fans, single-stack type, a vertical gap at least 75 cm wide and running all along the length of the kiln shall be provided between the vertical partition in which the fans are mounted [*see* **3.5.1.3** (Note)] and the side of the stack facing the fans, in addition to the vertical plenum spaces provided along both the side-walls. The gap shall be wide enough so that the air moving from the fans covers all parts of the stack.

c) The internal height of the chamber in case of internal fan kilns shall provide, in addition to the height occupied by the stack and trolleys (wherever used), for a minimum of 60-cm deep horizontal plenum space extending across the width of the kiln, either above or below the stack and interconnecting the two vertical plenum spaces that are provided on either side of the stack.

NOTE — This horizontal plenum space may be provided overhead to the stack or under the stack in internal fan type kilns, by erecting a horizontal false ceiling or false floor of sheet metal or wooden boards on channels or I-beams, extending over the entire length of the kiln but restricted in width to the width of the stack. It accommodates the fan equipment in the overhead internal fan and underground internal fan kiln, designs (*see* **3.5.1.3**), but is kept clear in the side mounted internal fan kiln design. This horizontal plenum space is not required to be provided in single stack external blower kilns, where the two vertical plenum spaces extending along both sides of the stack interconnect via ducts laid outside the kiln through an external blower.

3.5 Forced Air Circulation System

3.5.1 *Internal Fan Kilns*

3.5.1.1 Any of the systems, including overhead, underground or side-mounted internal fan or external blower type, may be adopted for the air circulation system provided the requirements with regard to plenum space width as laid down under **3.4.3** and with regard to air speeds through the stack layers as laid down under **2.4** are fulfilled.

3.5.1.2 Any design of fans may be used provided they are fully reversible and their capacity, number and location are adequate to fulfil the requirements with regard to air speeds laid down under **2.4**. Large diameter propeller fans rotating at low rev/min are preferable in internal fan kilns to small diameter fans worked at high rev/min, from the point of view of economy of power consumption and in the side mounted fan design in particular for uniform coverage of the stack. They should preferably be made of aluminium, though mild steel painted over with a corrosion-resistant paint may also be used.

3.5.1.3 The fans shall be mounted with the fan centres symmetrically located along the length of the stack in cross-circulation internal fan kilns. Cross-shaft mounting of the fans on individual shafts coming out of a side-wall of the kiln is to be preferred to mounting on a single longitudinal shaft coming out of an end wall, which requires careful additional baffling of each fan to produce cross-wise flow and ensure uniform air distribution.

NOTE — Cross-shaft fans in the overhead or underground fan kilns are mounted in holes provided for the purpose in a vertical central partition of sheet metal or wooden boards that is erected in the middle of the horizontal plenum space [*see* **3.4.3** (c)], dividing it in two parts all along the lengh of the kiln. Cross-shaft fans in the side-mounted fan kilns are mounted in a vertical partition that is erected on one side of the stack all along the length of the kiln and extending from the kiln floor to the false ceiling [*see* **3.4.3** (b)].

3.5.1.4 The fan shafts shall be of bright suitable steel and shall be suitably aligned and supported on adequate number of ball bearings mounted in plummer blocks and wall boxes, on pedestals. There shall be at least two pedestals and one wall box, with plummer blocks and ball bearings, to support each fan shaft in the cross-shaft mounting arrangement. The fan pedestals shall be securely mounted on channels or I-beams fixed across the walls of the chamber to avoid vibration.

Pedestals and the plummer blocks may be constructed from mild steel or cast iron. Arrangement shall be provided for greasing the bearings from outside without having to dismantle the plummer blocks. Fans, when installed, shall run without wobbling.

3.5.1.5 In cross-shaft mounting, a separate motor may be provided for each fan shaft or a single motor may be used for driving all the shafts suitably coupled to one another. Fan drive shall ensure that all fans operate at the same rev/min. Coupling should be preferably with V-pulleys and V- or link-belts of the required size depending upon rev/min and load. Motors should be totally enclosed, fan-cooled, suitable for continuous operation, and shall be reversible so that the air circulation can be reversed periodically. Diesel or steam engines may be used for driving the fans in locations where electric power is not available.

3.5.1.6 Adequately shaped sheet metal baffles should be installed in suitable positions in the chamber to smoothly guide the air circulation at sharp corners or bends and to prevent air short-circuiting across gaps in the stacking space. Where trolley loading is adopted, the trolley sides shall be baffled to prevent air short-circuiting across gap under them.

3.5.2 *External Blower Kilns*

3.5.2.1 Only a single blower is provided with external blower kilns. A duct below the kiln floor level, with openings at its top at regular intervals, shall be provided in the vertical plenum gap [*see* **3.4.3** (b)] along either side of the stack in an external blower kiln for even distribution and return of air to and from the entering and leaving air sides of the stack respectively These kiln ducts may be made of masonry or sheet metal. The discharge and suction side of the external blower are connected to these kiln ducts by means of distribution and return air ducts made of masonry, or canvas or sheet metal, provided with adequate thermal lagging and laid outside the kiln. The static pressure and capacity of the blower shall be adequate, and the cross section and taper of the external and internal duct system and the size of openings in the latter shall be adequately designed in accordance with air engineering principles so that the requirements with regard to air speed as laid down under **2.4** are fulfilled. Two by-pass ducts with dampers shall be suitably installed between the external distribution and return air ducts, so that their connection to the suction and delivery sides of the blower can be interchanged in order to produce reversible air circulation in the chamber.

3.5.2.2 The requirements with regard to baffling inside the chamber are identical to those for the internal fan kilns as laid down under **3.5.1.6.**

3.6 Heating System — Indirect heating by steam, furnace flue gases or electrically is generally adopted for heating the drying air in timber seasoning kilns. Direct-heated oil-fired furnace kilns, equipped with furnaces which ensure complete combustion and thus provide hot gases that do not discolour the stacked wood on contact, have not yet been used in this country.

3.6.1 *Steam Heating*

3.6.1.1 Any of the several types of pipe coils, namely plain-header coils, single-return-bend header coils, multiple-return-bend headers coils or unit coils, may be used for indirect heating by steam in a seasoning kiln. However, coils having asymmetric runs of pipe lengths and inlet or outlet headers fed or discharged end wise, which give rise to back-pressures and consequent air-trapping and water-logging, shall not be used. Coils longer than 8 m shall not be used as they pose difficulty in keeping clear of condensate. In kilns of longer lengths two separate coils, each extending half the kiln length, shall be preferred to a single coil extending the entire length. The coils shall be so designed and installed that the individual runs of pipe lengths have a pitch of 1 to 2 mm/m from the high to the low pressure end, to assist in discharge of condensate by gravity. They shall be installed lengthwise in cross circulation internal fan kilns and in the blower housing in external blower kilns.

3.6.1.2 The coils shall be made of black steam pipe C class. The pipe runs shall be minimum 25 mm nominal bore and the headers minimum 75 mm nominal bore. The runs may be of plain or fin-type pipe. The discs in case of fin-type pipe shall be firmly sweated, pressed, welded or wound to the pipe. When the discs used are of aluminium, a suitable bonding material to permit rapid heat transfer from the pipe to the discs shall be employed. The coil before installation shall be hydraulically tested up to 10·5 kg/cm^2.

3.6.1.3 Steam coils shall be drained through steam traps of sufficient capacity to keep them clear of condensate. As a rough guide, a steam coil in a kiln of stacking capacity 14 m^3 of timber in a charge (calculated in accordance with **3.4.1**) shall be provided with a steam trap of discharging capacity 180 kg of condensate per hour. Where more than one coil are worked simultaneously in a kiln, each coil shall be individually trapped to prevent the condensate from short-circuiting from one coil to another. Where more than one coil are worked alternately, they may all drain into a single trap of sufficient capacity but a stop valve shall be provided between each coil and the trap to prevent the hot condensate from the operating coil filling up the idle coils.

The steam traps shall be installed below and close to the coils that they drain, to facilitate gravity drainage and to prevent water-logging and air binding in the drainage pipes between coils and traps. A by-pass line with stop valves shall be installed around each trap, to vent air and steam binding in the drainage pipe between coil and trap and to enable the trap to be removed for repairs without shutting off the coil. A strainer shall be installed ahead of each trap to eliminate accumulation of dirt.

3.6.1.4 The number of pipe runs in a coil (radiating surface) shall suffice to raise the kiln to the operating temperatures from the ambient within reasonably short periods, say about 1½ hours, with a full load of green timber and without addition of live steam to the kiln air, using steam supply of the available characteristics (*see also* **2.2**).

3.6.1.5 Low-pressure saturated steam is generally used. A boiler oJ sufficient evaporative capacity shall be provided with any kiln to maintain working pressures up to 5·6 kg/cm^2 at the coils with a full load of green timber.

NOTE — For this, as a rough guide, a boiler of evaporative capacity 270 kg of water per hour shall be provided for a kiln of stacking capacity 14 m^3 of timber in a charge. Where kiln chambers are installed in pairs and staggered charging is practicable, so that one kiln is loaded with green timber when the timber charge in the other is nearing completion of drying, a boiler of evaporative capacity 360 kg of water per hour shall be provided for a pair of kilns, each of stacking capacity 14 m^3 of timber in a charge.

3.6.2 *Furnace Heating* — A kiln may be indirectly heated by passing flue gases, produced by burning oil or wood-waste in a furnace, through a pipe system installed inside the kiln chamber and connected to the furnace at one end and to a discharge chimney at the other end.

3.6.2.1 Flue gas pipes shall be of metal. They shall be of sufficient wall thickness for long service life under corrosive conditions and of sufficient internal bore (not less 7·5 cm) to permit easy passage of the hot gases under the suction arrangement adopted for the purpose which may be forced by means of a blower or thermal by chimney action. The pipes shall be installed so that the heat can be distributed uniformly throughout the kiln. They shall be long enough so that most of the heat is radiated within the kiln and not lost to the outside air. The design of flue pipes shall permit ready dismantling for periodic cleaning of soot depositing on the interior.

3.6.2.2 The furnace shall be installed at a lower level than the flue pipes and the chimney at a higher level.

3.6.3 *Electrical Heating* — Electrical heaters in kilns shall be tubular or strip heaters. The heating element shall be totally enclosed in corrosion-proof alloy metal casing and shall be properly insulated in the interior from the casing. The heaters shall be installed so as to distribute heat uniformly throughout the kiln, with their power connection ends taken out of the kiln interior wall to eliminate exposure to the kiln air.

3.7 Additional Humidification System—Additional humidification is essential in a kiln to prevent drying defects, such as surface and end cracking, splitting, etc, as well as for equalization of moisture content and relief of case hardening stresses in the last stages of kiln drying.

3.7.1 In steam-heated kilns, perforated steam spray lines are installed for mixing live steam with the kiln air. These shall be made of plain 25 mm nominal bore steam pipe with spray holes or jets or nozzles spaced 30 to 90 cm apart, and shall be installed close to the fans or blower so that the spray gets thoroughly mixed with the circulating air before it reaches the timber. In cross circulation internal fan kilns, the best position is in the vertical plenum spaces on either side of the stack and at a level with the false ceiling. If installed in any other position, suitable arrangements shall be provided to ensure that any condensed water is drained away without dripping on to the timber stack. The steam sprays shall be installed in the external blower housing in external blower kilns. All steam sprays shall be so installed that the steam does not impinge directly on timber, heating coils, trolley and trolley tracks, or on fans. Low pressure steam is preferable for steam sprays to high pressure steam, as the former possesses higher degree of saturation and is thus better suited for maintaining very high humidities as per the range specified under clause **2.3**. Where the steam supply is not wet enough to obtain the higher humidities, water shall be injected directly into the steam spray line to add moisture to the steam.

3.7.2 Additional humidification in furnace-heated kilns is provided by generating steam at atmospheric pressure by means of an auxiliary flue gases pipe coil installed in a water-vessel within or outside the kiln, or by means of water sprays. Nozzle sprays with water-feed under pump pressures or spinning disc sprays with water-feed at tap pressure may be adopted. Water sprays, where used, shall be capable of converting the feed water into a fine mist. An arrangement for pre-heating the feed water should preferably be provided for ready vaporization of the mist. Suitable drainage system shall be provided for readily removing the water that inevitably collects on the kiln floor or walls due to the coarser portion of the mist settling on them. The steam sprays provided with the auxiliary steam generating system, where used, shall be designed in accordance with the requirements laid down under **3.7.1**.

3.7.3 Additional humidification in electrically-heated kilns is generally provided by electrical generation of steam at atmospheric pressure in an auxiliary water-vessel outside the kiln. Electrode heating or heating by means of totally enclosed resistance-heating elements fully immersed in the water-vessel may be adopted for steam generation. A constant water-level arrangement shall be provided with the water-vessel to keep the electrodes or heating elements immersed all the time, and the unit shall be properly earthed. It is desirable that the water-feed should be pre-treated to remove calcareous matter that tends to deposit on the electrodes or the heating elements and reduce efficiency of steam generation in course of service.

3.8 Venting System — Some means of removing excess moisture from a kiln is essential to maintain desired relative humidity conditions during drying. This is accomplished by a system of exhaust vents or chimneys and fresh-air intake openings, suitably located relative to the fans or the blower.

3.8.1 The number and location of vents in a kiln shall be such as to ensure uniform venting throughout the kiln. Exhaust vents or chimneys shall be located on the high pressure side of the fans or blower and the fresh-air intake openings on the low-pressure side.

3.8.2 In internal fan kilns, cross-shaft type, both exhaust and intake may be through two rows of vent openings or chimneys with adjustable lids provided in the kiln roof. Both lines of vents are opened at the same time, with the line of vents on the high-pressure side of the fan working as fresh-air intake vents when direction of air circulation is reversed. Alternatively, two rows of chimneys may be provided in the kiln roof for exhaust, and two fresh-air ducts (closed at one end by adjustable dampers and with opening spaced at regular intervals on their tops) running the entire length of the kiln below the floor level for intake. Only one row of roof chimneys that happens to be on the high-pressure side of the fan and the corresponding fresh-air duct on the low-pressure side are opened at a time, depending upon the direction of air circulation. In overhead or underground fan designs, the rows of roof chimneys or vents and the sub-floor fresh-air intake ducts (when used) shall be located coincident with the vertical plenum gaps provided on both sides of the stack [*see* **3.4.3** (b)]. In side-mounted fan designs, one row of roof chimneys or vents and one fresh-air intake duct (when used) shall be located coincident with the vertical plenum gap on the side of the kiln on which the fan is installed, and the other row of roof chimneys or vents and fresh-air duct (when used) shall be coincident with the gap that is allowed between the vertical fan partition and the side of the stack [*see* **3.4.3** (b)]. The chimneys or vents in the latter position shall extend through the kiln roof and false ceiling into the gap between the fan-partition and stack-side.

3.8.3 In internal fan kilns, overhead longitudinal shaft type, a single row of roof chimneys or vents is provided, half of them working for exhaust and the other half for fresh-air intake. The vents or chimneys shall be located directly over the fan shaft, alternate ones being on the high- and low-pressure sides of the fans.

3.8.4 In external blower kilns, exhaust vents may be located in the blower housing or in the kiln roof. When in the blower housing, a single exhaust chimney or vent shall be provided on the pressure side of the blower and ahead of the heating coil, so that the kiln air entering the blower is vented before reheating. When in the kiln roof, two rows of exhaust chimneys or vents coincident with the vertical plenum gaps on both sides of the kiln shall be provided. Only one of these rows of vents will be opened at a time, depending upon the direction of air circulation. Fresh-air intake doors or openings shall be provided in the blower housing on the low-pressure side of the blower.

3.8.5 The number and size of vent openings provided shall enable relative humidity to be reduced to 35 percent at the operating temperatures within a reasonably short period (say 15 minutes), with a full load of green timber and with additional humidification fully cut out.

3.9 Control System — Drying conditions control in kilns may be manual or automatic. Control has to be provided for the flow of heat to the heating system, supply of steam or water for the sprays in the humidification system and for the adjustment of vent openings in the venting system. Control equipment varies with the mode of heating and humidification adopted.

3.9.1 *Manual Control Equipment*

3.9.1.1 In steam-heated kilns a hand valve of the globe type shall be installed between the main feed line and each individual heating coil and steam-spray pipe and also in the drain pipe between each heating coil and the steam trap. In addition, a hand valve shall be provided in the by-pass line around each steam trap (*see* **3.6.1.3**). A pressure reducing hand valve shall be installed in the main feed line between the boiler and the kiln. A pressure gauge shall be installed in the main feed line ahead of the pressure-reducing valve and another ahead of the distribution pipe-line network to the kiln. Dampers of roof chimneys or vents shall be linked together by means of a wire rope passing over pulleys, with a handle at one end for convenient adjustment of vent openings. Dampers of fresh-air intake duct shall be adjustable smoothly.

3.9.1.2 In furnace-heated kilns, apart from the manual adjustment of fuel feed rate (oil or wood), manually adjustable dampers shall be incorporated in the flue gases pipe system to regulate heat flow into the kiln. Where auxiliary steam generation is adopted for humidification (*see* **3.7.2**), a manually adjustable damper shall be provided for the auxiliary flue gases pipe coil installed in the water vessel to control heat supply for steam generation and a hand valve shall be provided in the steam spray line for controlling live steam supply to the kiln for humidification. Where water sprays are adopted for humidification, a hand valve for regulating water-feed rate to the spray shall be provided to control humidification, in addition to manual switching-off of the pump or spinning disc motor (*see* **3.7.2**). Venting control shall be similar to that described under **3.9.1.1**.

3.9.1.3 Electrically-heated kilns may be controlled by manually switching-off the current to strip or tubular electric heaters and to the electrodes or resistance-heating elements incorporated in the water-vessel for auxiliary steam generation (*see* **3.7.3**). Venting control shall be similar to that described under **3.9.1.1**.

3.9.2 *Automatic Control Equipment*

3.9.2.1 In steam-heated kilns, diaphragm type valves operated by compressed air or motorized valves operated by electricity may be used to control steam supply to heating coils as well as to the steam spray pipes. A dry- and wet-bulb temperature indicator or recorder, preferably mercury- or vapour-filled extension-tube type, in which the temperature sensitive element can control electrical switching, or mechanical opening and closing of a compressed air supply, has to be used with such valves. The mechanical arrangement can be used to control air supply to diaphragm valves directly. The electrical switching arrangement can be used to control motorized valves directly, but can also be used to control air supply to diaphragm valves through an auxiliary 3-way solenoid valve incorporated in the air supply line. The automatic valves shall be installed between the main steam supply line and the heating coils and between the main line and the steam spray lines. An automatic pressure-reducing valve may be installed in the main feed line between the boiler and the kiln, but it can only prevent steam pressures from going above a pre-set maximum and will not maintain a fixed minimum pressure. In other remaining positions, such as in the drain lines between heating coils and steam traps and in the by-pass lines around steam traps hand valves shall be installed as in the manual control system (*see* **3.9.1.1**). Two pressure gauges shall also be installed in positions identical to the manual control system. Roof vents may also be automatically operated by compressed air or by electrical motors in conjunction with a dry- and wet-bulb thermostat controlling a mechanical air-supply closing-and-opening arrangement or an electrical switching arrangement.

3.9.2.2 In furnace-heated kiln using oil-firing, diaphragm, motorized or solenoid valves in conjunction with suitable thermostating system as described under **3.9.2.1** may be used to control fuel-feed rates to the oil burners. A compressed-air or electrical-motor operated system akin to that described under **3.9.2.1** above may be adopted for automatic control of roof vents as well as for control of dampers provided in the flue-gas pipe system for kiln heating and in the flue-gas coil system for auxiliary spray-steam generation (wherever used). Where water sprays are used, water supply can be arranged through a diaphragm, motorized or solenoid valve and electric power to the pump or spinning disc motor can be supplied through magnetic switches, that can be controlled by suitable thermostating arrangement. Fuel-feed rate in waste-wood fired furnaces can also be thermostated by motor-operated control of feed from a hopper installed over the furnace. The control of rest of the operations, such as adjustment of dampers in the flue-gas pipe system for kiln heating, water-spray humidification and kiln venting is similar to that described for oil-fired furnace kilns.

3.9.2.3 In electrically-heated kilns, the electrical heaters, electrical arrangement for auxiliary spray-steam generation and roof-vent motors can all be thermostatically controlled if the power is supplied to them individually through a system of magnetic switches and relays, actuated by a dry- and wet-bulb temperature thermostat provided with electrical switching arrangement.

4. AUXILIARY KILN EQUIPMENT

4.1 Temperature-Measurement Instruments — Two types of temperature-measuring instruments are available:

(a) Visual or Indicating, and (b) Recording. Recording type instruments are to be preferred to indicating type as they enable direct checking of operation of kiln run. Two kinds of measuring systems that are in vogue in kiln drying work are: (a) Mercury-in-glass indicating thermometers; and (b) Extension-tube, mercury-filled, gas-filled or vapour-filled thermometers consisting of a copper covered bulb, capillary tube and a spiral pressure-sensitive element to which a pointer or pen is attached for indication or recording. The latter system is quite rugged for kiln use and enables distant reading or recording without disturbing kiln operation, though it is a bit sluggish in response and less accurate than the former system. This system, when designed to thermostatically control supply of compressed air or electric current to diaphragm, motorized or solenoid valves in the heating and humidifying systems and to the control-motor or other mechanical device for regulating vents, is also very suitable for automatic drying conditions control in kilns. For kiln use, both these systems are supplied with two thermometers — one for wet-bulb and the other for dry-bulb temperature measurement, to enable both the temperature and relative humidity to be measured simultaneously.

4.1.1 It is recommended that each kiln chamber be provided with at least one dry- and wet-bulb temperature recorder of the extension-tube type for distant recording and at least two dry- and wet-bulb hand hygrometers of the mercury-in-glass type, one for occasional checking of the recorder readings and another to be placed on the side of the stack opposite to the recorder to guide kiln operation under reversed circulation when the circulating air enters the stack from that side. If recorders cannot be provided, two dry- and wet-bulb temperature distant-indicating instruments and two hand-hygrometers shall be used.

4.1.2 The instruments shall have a range of 20 to 100°C. The bulbs and capillaries of distant-recording or indicating type instruments shall be adequately covered or armoured for protection against corrosio in kiln atmosphere. The capillary length shall be sufficient to enable installation of the sensing bulbs at middle position along the length of the stack. The readings shall depend upon bulb temperature only and shall be independent of the length of capillary inserted inside the kiln.

4.2 Laboratory Equipment — For testing the moisture content of wood and for determining the rate of drying of timber in a kiln charge, the following equipment shall be provided in any kiln installation:

a) Equipment for sawing small test sections.

NOTE — Hand-sawing is possible. A 30 cm wheel, motor-driven fine-cutting handsaw is preferable.

b) *Beranger scales* — capacity 10 kg, with set of weights.

c) *Physical balance* — capacity 250 g, sensitiveness 5 mg, with set of weights.

d) Thermostatically controlled, ventilated drying oven, range up to 105°C, differential ±2°C.

In addition, an electrical moisture-meter capable of reading wood moisture contents in the range 8 to 25 percent may be provided for extensive rapid checking of kiln-dried timber.

5. TESTING KILNS

5.1 A kiln may be tested for conformity to the minimum performance requirements laid down under **5.2** to **5.6**. The tests described below are functional in character.

5.2 The stacking space in the kiln shall be fully stacked with 2·5 cm thick square-edged planks using 20 mm thick crossers. Gaps if any, particularly in length and height or under the trolleys (where used), shall be carefully baffled. The planks in any layer shall also be stacked edge-to-edge without gaps, and the sides and ends of the stack shall be strictly vertical. At the time of stacking the charge, 18 matched kiln samples of identical dimensions, species, cut and structural characteristics (as far as possible) shall be prepared and 9 samples shall be placed on either side of the stack at evenly distributed positions along the length and height.

5.3 After closing all doors, chimneys or vents and adjusting the fan-drive system to give the prescribed rev/min the fans shall be worked. The air speed between the stack layers shall be measured in at least 9 different evenly distributed positions along the length and height by inserting the probe of a suitable air-speed measuring instrument up to middle position across the width of the stack. The air speeds shall then be measured again in identical positions between the stack layers, with the air circulation reversed. The results of the 18 readings so obtained shall conform to the requirements laid down under **2.4**.

NOTE — Hot-wire anemometers and venturi-tube meters having small probes are best suited for this work. The simple smoke test can also be employed. Vane-anemometers tend to give erratic readings in restricted spaces.

5.4 After checking the heating, humidifying and venting systems for working order the kiln shall be heated up and additional humidification provided so as to attain the dry- and wet-bulb temperatures corresponding to the initial step of the drying schedule applicable, on the entering air side of the stack, within a period of about 1½ hours. The time for attaining these temperatures shall be noted and shall conform to the requirements of **2.2** and **2.3**.

5.5 After temperatures in the kiln have stabilized at the desired values, a dry- and wet-bulb temperature survey shall be made in at least 9 different evenly distributed positions along the length and height on the entering air side of the stack with the help of hand hygrometers. Readings shall then be repeated at corresponding positions on the other side of the stack with reversed air circulation. The results of the 9 readings on either side shall separately conform to the requirements with regard to unformity of dry- and wet-bulb temperatures as laid down under **2.6** and **2.7**.

5.6 The test charge shall, thereafter, be dried to the desired final average moisture content, following the drying schedule applicable to the stock and reversing the air circulation every 6 hours. Daily records of moisture content of the 18 matched kiln samples shall be maintained and drying curves of moisture content against drying time plotted for all the samples. Drying rates at identical moisture content levels shall be computed from the drying curves for the different samples at different stages of drying, and tabulated for comparison between different positions within the stack. On comparison, the drying rates at identical moisture content levels as well as the end moisture contents of samples placed in different positions shall not show wide differences.

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